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INVESTIGATIONS ON THE PLATINUM METALS

VII. ARC SPECTRA OF THE PLATINUM METALS (4500A to 9000A)

By W. F. Meggers

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[Part of Vol. 20]

INVESTIGATIONS ON THE PLATINUM METALS

VII. ARC SPECTRA OF THE PLATINUM METALS (4500A to 9000A)

BY

W. F. MEGGERS, Physicist
Bureau of Standards

January 23, 1925

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INVESTIGATIONS ON THE PLATINUM METALS[1]

VII. ARC SPECTRA OF THE PLATINUM METALS (4500A TO 9000A)

By W. F. Meggers

ABSTRACT

In other papers of this series mention has been made of the use of the spectrograph to follow the progress of chemical separation of the platinum metals. When materials approximating spectroscopic purity were prepared in this bureau an investigation of the arc spectra was undertaken primarily for the purpose of securing data in the red and adjacent infra-red regions where no data on the emission spectra of the platinum metals existed. Specially sensitized plates were employed to record the spectra with large diffraction gratings, and many hundreds of new lines were measured in the yellow, orange, red, and infra-red regions. Comparison with previous observations in the regions common to the old and to the new measurements showed that the former were incomplete. This led to an extension of the latter to shorter waves, thus including almost all of the visible spectrum, and made it possible to carry out a more extensive comparison of the spectroscopic purity of the materials used by the different observers. New values of wave lengths and estimated relative intensities are given in six tables as follows: 1,260 lines for ruthenium (4498.16 to 8867.84A), 572 lines for rhodium (4503.80 to 8615.23A), 172 lines for palladium (4497.66 to 9234.02A), 942 lines for osmium (4500.74 to 8644.8A), 605 lines for iridium (4500.97 to 8426.11A), and 239 lines for platinum (4498.75 to 8762.48A). The wave lengths were measured relative to the secondary standards in the spectrum of the iron arc, and each value is, in general, the mean of from 2 to 10 determinations. The probable error of these values rarely exceeds one one-hundredth of an Angstrom unit. Six short tables giving lines ascribed to platinum metals by other observers, but not visible on the new spectrograms are subjoined to the major tables, and most of these lines are identified as impurities in the materials at the disposal of the earlier observers. Intercomparison of the results of the new measurements indicate that the metals used in this investigation were exceptionally pure, since even the most intense lines characteristic of each particular element rarely, if ever, appeared in the spectra of the other elements.

[1] (I) "The preparation of pure platinum," by Edward Wichers, Journ. Am. Chem. Soc., 43, p. 1268; 1921; (II) "Investigations on platinum metals at the Bureau of Standards," by Edward Wichers and Louis Jordan, Trans. Am. Electrochem. Soc., 43, p. 385; 1923; (III) "The preparation of platinum and of platinum-rhodium alloy for thermocouples," by R. P. Neville, Trans. Am. Electrochem. Soc., 43, p. 371; 1923; (IV) "Determination of Iridium in Platinum Alloys by the Method of Fusion With Lead," by Raleigh Gilchrist, B. S., Sci. Papers, 19 (No. 483), p. 325; 1924; (V) "The analytical separation of copper from the platinum metals," by W. H. Swanger and Edward Wichers, Journ. Am. Chem. Soc. 46, p. 1814; 1924; (VI) "The analytical separation of rhodium from platinum," by Edward Wichers, Journ. Am. Chem. Soc., 46, p. 1818; 1924.

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I. INTRODUCTION

As has been stated in Paper II of this series, the Bureau of Standards several years ago began a comprehensive investigation involving the purification of all metals of the platinum group and critical studies of analytical separation, the melting and mechanical working of the pure metals and their alloys, the study of selected alloys with respect to their suitability for platinum ware, and the determination of physical properties of both metals and alloys. In the paper just cited and in other papers of the series mention is made of the use of the spectograph to control the process of purification of these metals. With this first phase of the investigation well advanced, it has been possible to begin the last phase mentioned, viz, determination of the physical properties of the pure metals. The electric arc emission spectra of the six metals—ruthenium, rhodium, palladium, osmium, iridium, and platinum—have been made the object of special study in the visible and adjacent infra-red spectral regions, and the purpose of this paper is to present the data thus obtained.

These data are similar to others published in a series of papers [2] dealing with arc spectra in the yellow, red, and infra-red regions with which the spectroscopy section of this bureau has been more or less concerned for the past 10 years. The initial object of this program was to extend the spectroscopic data for the longer waves and thus contribute to a complete description of the standard arc spectra of all the chemical elements. The production of the platinum metals in a state of high purity by the chemists of this bureau has been very favorable toward forwarding this part of the program. A study was completed for wave lengths greater than 5500A more than a year ago, but when the tables were compiled it appeared, from those portions which overlapped the earlier observations, very desirable to extend the new measurements to the violet. This was with the thought that it would permit a more satisfactory comparison of the materials and results of the different observers. The comparisons, when made, indicated that it might further be advisable to

[2] B. S. Sci. Papers, Nos. 312, 324, 329, 345, 372, 411, 421, and 442.

reexamine the spectra of these pure metals in the ultra-violet. Necessity for the postponement of this additional work has led to the decision to publish, without further delay, the results thus far obtained for wave lengths greater than 4500A.

Only three earlier investigations on the arc spectra of the platinum metals permit of a comparison of values with those given here. The first was by Professor Kayser,[3] who, in 1896, carefully measured the spectra throughout the range of wave lengths from ultra-violet to yellow. The second was by Eder and Valenta,[4] who, in 1910, extended Kayser's tables to the orange and red, but recorded only the stronger lines. The third was by Exner and Haschek,[5] who, in 1911, published their extensive observations on The Spectra of Elements at Normal Pressure. In this case, too, the data are incomplete, especially for the longer waves in the visible spectrum. In all three cases the wave-length values were based on the Rowland scale. With one exception, referred to below in the discussion on platinum, up to the present time no values for the arc spectra of the platinum metals have been determined relative to the new system of international standards adopted since 1910.

II. APPARATUS AND METHODS

Two different concave diffraction gratings each of 640 cm radius were used for obtaining the spectrograms. These were interchangeable in the mounting which has been described in another paper.[6] For the region to the red of 6000A an Anderson grating of 7,500 lines per inch giving a scale of 10.4A per mm was used because it gives an exceptionally bright spectrum, so desirable for speed in the infra-red. The final results for wave lengths from 4500 to 6000A are compiled from spectrograms made with a Rowland grating with 20,000 lines per inch which gave a dispersion of 3.75A per mm. Some of these larger scale spectrograms extended beyond 7000A; for the longer waves the Rowland grating was considerably slower than the Anderson grating.

The spectograms were made on Schleussner ultra-rapid plates 40 cm long by 6 cm wide. These were about 1 mm thick and could, therefore, be bent to fit the focal curve of the grating and thus afford an equally sharp focus over the entire plate. For the region 4500 to 6000A the plates were stained with pinaverdol, from 5500 to 7500A pinacyanol was used, and dicyanin served from 6500A into the infra-red. The exposures averaged about 5 minutes in the blue, green, and yellow; 15 to 20 minutes for the orange and

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[3] H. Kayser, Abh. k. Akad. d. Wiss. Berlin, 1897; Astroph. Jour., 7, p. 93 and p. 173; 1898.

[4] Eder and Valenta, Sitzungsber. k. Akad. d. Wiss. Wien, 119, IIa, p. 519; 1910.

[5] Exner and Haschek, Die Spektren der Elementi bei Normalen Druck, II, 1911, Franz Deuticke, Leipzig und Wien.

[6] B. S. Sci. Paper No. 414.

red; and 1 hour for the infra-red. More lines would probably have been found in the infra-red if the exposures had been continued for two or more hours, but it was considered that the possible additions to wave-length data would not justify the consumption of large amounts of these costly pure metals.

Observers of arc spectra of the six elements in this group have been forced to use metal sponge or salts on electrodes of carbon or copper, except that platinum and palladium have generally been available in the form of ingots for use as arc electrodes. Thus, Kayser used salts of ruthenium, rhodium, osmium, and iridium on carbon electrodes in which he recognized the following impurities: Calcium, aluminum, sodium, manganese, chromium, nickel, titanium, etc. Eder and Valenta and Exner and Haschek used carbon electrodes in most of their exposures, necessitating the examination of each spectrogram for the particular lines which represented electrode materials or impurities. The use of carbon electrodes for spectra of the platinum metals is somewhat unsatisfactory, since, in addition to numerous impurities usually found even in the best carbon, it is very difficult, especially with high boiling-point metals, to suppress the complex spectra representing carbon compounds.

In the present investigations ingots of pure platinum and palladium were used as arc electrodes. The remaining metals were in the form of sponge, and attempts were first made to obtain suitable spectrograms of these with Acheson graphite, which has been found to be much purer than commercial carbon. The spectra due to carbon and its compounds, however, were usually strong enough to mask most of the others. This method of observing was, therefore, discarded and all spectrograms which have been measured here were made with electrodes of copper or silver. These metals are especially suitable for the investigation of the longer-wave spectra since they contain relatively few lines, and the characteristic colors of the arcs indicate whether the light is coming primarily from the electrode material or from the test samples placed upon them. The arc flames of both copper and silver have a distinct green color, consisting in the case of copper mainly of three deep green emission lines (5105.58, 5153.26, 5218.20A) and two yellow-green lines (5700.25, 5782.16A); while for silver the color is imparted mainly by two intense green lines (5209.08, 5465.49A). Elements whose spectra are characterized by a large number of lines none of which are overwhelming in intensity generally give a bluish-white color to the burning arc. Such is the case, for example, with ruthenium, rhodium, osmium, and iridium. When these metals are properly burned on copper or silver electrodes they change the arc color from green to white, and it is possible thus to photograph their spectra with almost complete suppression of all but the strongest lines from

the electrode materials. The arcs were operated with a potential of 240 volts and direct current of 5 to 6 amperes. A record of the weights of the electrodes and the exposure times for palladium and platinum showed that these metals were volatilized in the arc at the rate of about 1 g per hour.

The difficulty of chemically separating the six metals of the platinum group from each other has been a great handicap to spectroscopists who have attempted to describe the spectra with more or less completeness. It has been necessary heretofore to use impure materials and to intercompare the wave lengths and relative intensities of all lines in different spectrograms so as to identify the contaminations and properly assign each line to the element which it characterizes. Even when applied with great patience and rare judgment this procedure is objectionable, especially in dealing with such complex spectra as those of the platinum metals, and it may account in large part for the unsatisfactory descriptions which have been given to these spectra. Kayser states that he and Runge began extensive investigations of these spectra in 1894, but because of the impure state of the metals all of their spectrograms were discarded. Kayser repeated the investigation in 1896 with materials of somewhat higher purity prepared by Bettendorff for atomic-weight determinations. Even these were found spectrographically to be impure, and Kayser admits, for instance, that in striking from his list of Ir lines most of the coincidences with strong Ru lines some true Ir lines may have been removed. Eder and Valenta do not mention the source of their materials, but it is unlikely that their platinum metals were much purer than those at Kayser's disposal. They suspected their iridium of containing ruthenium and state that rhodium lines had to be eliminated from their measures of the ruthenium spectrum. The platinum metals which Exner and Haschek used were furnished by Heräus. In each case their spectra showed that they were dealing with impure materials, and it was necessary to subtract the lines of from 3 to 12 impurities from each of the spectrum tables. The impurities originating in the platinum metals and electrode materials used by these early observers will be referred to in more detail in connection with the results of the present investigation. The difficulty is stressed at this point for the purpose of emphasizing the fact that it has been apparently eliminated. That the platinum metals used in this examination are very pure, indeed, is evidenced by the wave-length tables given below. In the compilation of these tables only the lines due to copper or silver electrodes or their impurities and the atmospheric lines which are common to all open-air arc spectra have been removed; all the remaining lines which were measureable on the spectrograms are given. Intercomparison of these tables shows that the strongest lines of any one spectrum are

almost without exception positively absent from all the others. To be sure, in such complex spectra a considerable number of approximate coincidences of wave lengths may occur, and some of these which involve strong lines have been marked. It is probable, however, that most of these are purely fortuitous and can not be interpreted as mixed spectra.

III. RESULTS

The spectrograms were measured on a large engine whose smallest scale division is 0.001 mm, corresponding to 0.0104A on photographs made with the Anderson grating and to 0.0038A on plates exposed with the Rowland grating. All of the wave-length measurements are based on the internationally adopted values of secondary and tertiary standards in the spectrum of the iron arc.[7] Each wave length given in the following tables is, in general, the mean of from 2 to 10 determinations. Lines between 4500 and 7000A with intensities greater than 9 or 10 were accompanied by ghosts in the spectrograms made with the Rowland grating; additional values for the wave lengths of the parent lines were derived from measurements on these ghosts. In general, the probable error for lines of intensity 2 or more rarely exceeds one one-hundredth of an Angstrom unit. About 5 per cent of the lines of intensity 1 and half of those marked "0" were observed only once; the wave-length errors in these cases may be somewhat larger.

It is generally admitted that one of the most unsatisfactory features of spectrum tables is the estimation of relative intensities of the different lines. There does not appear to be any simple, reliable method for measuring the energy in each emission line, and the general practice for nearly half a century has, therefore, been to assign numbers to the lines, such numbers representing arbitrary intensity gradations. Most frequently spectroscopists have assigned intensity 1 to the weakest lines and 10 to the strongest. This is the scale which has heretofore been in use in this laboratory. It is also the range of estimates by Eder and Valenta and by Kayser, except that the last named has represented the very weak lines of the platinum metals by 0. Exner and Haschek have employed a somewhat wider range according to which the stronger lines are represented by tens or even hundreds of units.

The structures of a considerable number of complex spectra have recently found interpretation in the discovery of related groups of lines called multiplets, and the intensities of lines in each multiplet are apparently governed by definite rules.[8] This development emphasizes the importance of correct values for relative intensities and indicates that the actual range in most spectra should be greater than 1 to 10. In the present description of the arc spectra of the platinum metals an attempt has been made to use a new scale of

[7] Trans. Internat. Astron. Union, 1, p. 41; 1922.
[8] Burger and Dorgelo, Zeitschr. Physik., 23, p. 258; 1924.

intensities which may be defined as follows: Lines which were easily measurable under the microscope were called intensity 1, and whenever a line appeared in the Rowland-grating spectrograms to have first order ghosts of intensity 1 the intensity of the parent line was arbitrarily assigned the number 10. Lines of intensity 0 are difficult to make settings on, and the ghosts of lines whose intensities are 8 or 9 are assigned to this class. The relative values assigned to all other lines resulted from interpolated estimates, the values for very strong lines being based on the estimated intensities of their ghosts; for example, if the number 5 was assigned to a ghost, the intensity of the parent line was marked 50. It appears that such a procedure may be of considerable value in making quantitative distinctions if based upon a determination of the actual ratio between the energies of parent lines and ghosts.

Approximately 3,800 wave lengths are presented in the six tables which follow. The letters which occasionally appear in the intensity columns have the following meaning:

h = hazy.
H = very hazy.
d = double.
+g = ghost coincident.
n = band head.
v = shaded to violet.
l = shaded to red.

Short additional tables subjoined to each of the six major tables contain the lines ascribed by other observers to the platinum metals, but which did not appear on my spectrograms. It has been possible to identify most of these extra lines with impurities. A few in Kayser's lists have been recognized also as typographical errors. The wave lengths in the supplementary tables which were observed relative to Rowland's standards have been corrected to the international scale.

1. RUTHENIUM (Ru=101.7; Z=44)

Kayser measured 302 lines in the arc spectrum of ruthenium between wave lengths 4508 and 5887A. He used material containing considerable Os, some Ir, and a trace of Pt. After eliminating rhodium lines, etc., Eder and Valenta gave 169 lines between 5815 and 7087A. The ruthenium chloride used by Exner and Haschek contained Ca, Mg, Pd, Pt, and Rh. They gave 314 lines from 4508 to 6690A for Ru. In table 1 are presented 1,260 lines from 4498 to 8868A. Among these are included all the lines given by the other observers except those collected in Table 1*a* which did not appear on my plates. These are for the most part lines of low intensity and may be explained as known or unknown impurities and, in a few cases, perhaps as typographical errors. The last column in Table 1*a* contains some suggested corrections.

TABLE 1.—*Arc spectrum of ruthenium*

λ I. A.	Intensity and notes	λ I. A.	Intensity and notes	λ I. A.	Intensity and notes	λ I. A.	Intensity and notes
4498.16	15	4599.10	15	4701.52	0	4804.87	8
4505.64	1	4600.55	2,h	05.17	1	06.19	3
08.04	3	01.75	6	07.65	1	07.62	1
08.56	5	02.81	3	09.48	35	09.70	2,+g
10.12	8	05.66	5	10.97	2	12.21	1
11.20	7	06.81	2,h	11.99	3	12.84	1
14.85	1	07.80	0	12.50	2	13.23	2
16.27	3	08.68	1	13.40	2	14.14	0
16.90	10	09.02	0	13.58	0	14.71	2
17.82	10	10.50	2	14.85	0	15.50	15
20.94	9	12.31	4	15.62	1	17.33	3
23.98	0	15.44	1	16.04	4	22.56	3
25.19	1,h	15.80	0	18.07	3	24.35	1
25.50	1	16.12	1	18.85	2	25.73	1
25.96	1	17.66	3	20.91	5	26.17	2
26.43	2	18.06	1	21.86	1	26.55	2
29.07	2	18.79	2	23.23	2	27.70	1
30.85	8	20.03	1	23.62	1	27.86	1
31.80	2	24.35	2	24.79	3	28.68	2
32.46	2	24.48	0	26.23	0	31.63	1
33.30	0	26.03	3	27.59	1	33.00	10
34.51	1	28.32	3	28.64	1	36.42	1
35.59	3	29.02	0	28.80	0, Ir?	38.16	2
36.33	1	30.45	2	31.34	10	38.99	8
37.46	1	30.74	1	33.47	12	39.75	4
38.69	2,Ir?	31.09	1,+g	34.47	0	41.76	2
40.88	1	31.74	0	35.21	1	43.78	2,+g
42.44	3	33.17	1	36.60	0	44.54	9
43.70	4	33.51	1	38.40	5	45.91	2
45.42	0	34.76	1	40.33	2	46.11	1
45.73	1,Ir?	35.66	10	41.26	2, H	46.82	0
46.95	4	38.40	3	42.21	0	47.86	2
47.33	7	39.31	3	43.02	5	48.17	2
47.86	6	40.40	2,h,+g	43.66	1	51.94	2
49.42	3	40.99	2	43.99	1	52.59	1
52.10	5	42.41	2	44.64	1	52.90	1
54.51	50	42.62	2	45.86	1	53.51	2
56.13	2	45.06	10	48.20	1, d	54.57	6
57.82	0	46.80	1	49.16	1	55.94	1
59.97	7	47.61	15	49.81	1	58.00	1
62.59	3	48.18	2	51.00	2	59.27	1
64.69	5	50.22	1	52.14	3	60.15	1
66.12	0	52.53	8	53.83	2	60.46	2
66.71	1	53.74	2	56.23	8	61.86	7
67.92	1	54.31	10	57.84	20	62.35	0
68.22	1	54.82	2	61.52	1	63.09	3
69.26	0	56.42	3	64.41	7	65.08	4
70.25	2	57.42	2,h	66.65	1	68.03	1
70.72	0	60.64	1	67.14	3	69.16	25
72.80	1	62.28	1,h	69.30	9	69.79	3
73.54	0	62.51	2	70.73	0	71.37	0
73.97	0	65.00	2	71.78	0	71.57	1
75.76	1	69.14	3	72.11	0	74.33	3
76.34	1	69.96	8	73.15	4	75.01	6
77.42	1	71.38	1	73.99	5	75.97	1,h
80.08	7	73.86	0	76.89	1	77.41	3
84.45	30	74.62	9	81.11	2	77.88	2
86.54	0	75.19	1	81.76	3	82.66	3
87.09	4	81.40	2, h	83.29	2	82.89	0
87.89	1,+g?	81.79	10	84.27	6	83.74	0
89.58	2	83.11	2	85.09	1	85.01	2
91.11	6	c 84.02	10	87.34	2	86.35	1
91.58	2	85.79	3	90.05	1	87.55	1
92.02	1	90.11	15	90.82	1,+g?	88.60	2
92.50	7	91.91	1	93.72	0	89.83	2
93.08	1	92.93	1	94.38	6	91.99	0
93.22	1	95.28	2	95.57	6	92.84	2
95.39	1,h	97.59	0	4798.43	5	94.22	1
96.69	6	4698.72	1	4801.17	3	95.28	6
4597.71	0	4700.29	1	4802.91	2	4895.60	12

TABLE 1.—*Arc spectrum of ruthenium*—Continued

λ I. A.	Intensity and notes	λ I. A.	Intensity and notes	λ I. A.	Intensity and notes	λ I. A.	Intensity and notes
4899.23	6	5010.60	5	5132.72	0	5266.23	3
4901.06	3	11.22	9	33.87	7	66.46	3
01.85	3	14.32	0	34.17	6	66.83	4
03.05	15	14.95	8	36.55	25	69.15	1
04.56	2	15.99	0	42.32	2	71.17	1
05.01	4	16.81	1	42.76	8	71.45	0
07.88	8	18.96	5	44.51	0	72.10	2
10.23	4	20.31	2	45.90	1	73.46	1
11.58	3	23.15	0	47.24	10	74.05	2
13.26	2	26.17	8	49.05	1	75.05	4,h
14.18	3	28.16	6	49.73	2, Os?	75.76	2
17.35	2	30.16	0,h	51.06	8	78.37	2
18.37	1	31.91	1	52.09	0	80.05	2
19.03	3	32.35	0	53.19	4, +Cu?	80.81	4
19.64	1	32.90	1	54.58	2	82.69	0, h
21.08	12	37.01	1	55.12	12	84.08	10
23.70	1	39.03	2	55.49	0, Rh?	84.41	2
24.53	1	39.61	5	56.20	1	91.16	6
30.93	1	40.34	5	59.98	5	91.89	1
31.72	0	40.74	6	66.21	1	93.27	1
32.38	0	41.36	3	68.06	3	96.23	1
34.60	1	41.97	2	68.62	2	5299.93	0
35.63	4	45.42	4	70.08	2	5303.30	0
36.23	2	47.30	6	71.02	40	04.85	7
37.20	3,h	52.94	4	73.94	2,h	05.85	3
38.43	10	57.33	30	77.97	2, Ir?	06.44	3
39.86	0	57.68	2	78.64	1, h	07.27	4
40.14	1	58.77	0	84.72	2	09.26	20
41.57	1	62.65	4	86.52	1	15.32	4
42.34	1,h	63.17	1	87.25	0	16.57	1
43.99	2	64.77	2	88.36	1	17.92	1
44.40	1	66.65	2	89.74	3,+g	18.74	1
45.24	0	67.62	1	91.73	0	19.98	0,h
51.25	1	69.04	0	93.00	1, Rh?	20.81	2
55.25	10	69.76	0	95.01	10	25.37	0
59.85	6	70.99	3	95.40	0	27.06	2
62.89	0	72.97	7	97.05	2	28.01	3
64.02	1,h	74.75	1	5199.88	6	28.81	1
64.87	2	75.62	1	5202.12	4	32.92	6
66.11	1	76.07	5	02.89	1	34.69	9
67.38	1	76.34	7	05.31	1	35.92	10
67.62	2	79.45	5	11.07	0	38.24	0
68.01	3	80.72	1	13.40	7	39.22	0
68.87	7	82.90	1	14.07	3	40.13	1,+g
70.19	1	84.00	1	19.07	1	41.72	1
70.79	1	84.58	1, h	23.54	7	42.22	1
71.38	1	86.75	5	24.13	1	43.30	1
73.51	0	90.07	3	25.07	3	45.53	1
74.10	5	93.82	10	26.36	2	46.79	2
75.37	4	94.62	1	27.27	3	47.20	0
76.18	9	5096.21	2	30.94	1	48.13	3
77.21	1	5100.84	2	34.83	1, Pd?	48.58	0
77.97	2	01.36	5	35.58	4	49.82	0
80.35	9	01.72	3	36.95	2	50.40	4
83.12	1	04.38	0	40.78	0	53.67	2
83.44	4	06.54	4	42.37	7	54.95	2
84.69	2	07.07	8	42.94	5	57.83	0, h
87.25	5	11.24	1	44.24	1	59.59	4
88.44	0	13.01	3, h	44.93	2	61.75	20
91.20	1	14.57	2	45.43	3	65.61	4
91.93	0	14.98	3	46.84	1	69.27	1
92.73	7	18.13	0	50.46	2	73.28	2, d
94.89	2	19.87	1	51.63	8	74.38	0
96.24	1	21.41	1	55.45	0	77.06	2
98.03	2	22.39	0	56.34	0	77.83	10
99.00	0	22.95	2	57.06	8	78.69	0
4999.53	1	23.74	4	57.84	0	80.12	0
5002.63	2	26.78	2	63.13	0	83.31	2,h,+g
03.53	3	27.25	5	63.95	4	84.11	1
5005.24	4	5129.27	1	5265.92	2	5385.88	7

TABLE 1.—*Arc spectrum of ruthenium*—Continued

λ I. A.	Intensity and notes	λ I. A.	Intensity and notes	λ I. A.	Intensity and notes	λ I. A.	Intensity and notes
5388.61	2	5512.39	4	5678.22	1	5814.99	10
91.57	1	17.86	3	79.22	0	19.99	1
95.38	2	19.14	1, h	79.62	4	25.28	1
97.90	1, h	21.81	3	79.94	0	25.84	2
5399.39	0, h	22.63	1, h	81.52	1	27.32	2, h
5401.00	15	24.15	1	82.27	0	28.06	4
01.39	7	24.77	1, h	88.83	3	28.40	2
03.29	0	26.09	1, n, l	92.11	2	30.84	1
05.27	2	26.32	2, n, l	93.03	5	33.21	5
07.38	0	30.99	3	94.46	3	33.40	4
10.36	2	40.66	5	96.37	2	36.54	0
10.82	0	42.08	1, h	99.06	20	39.02	0, h
12.82	1	42.32	1	5699.57	3	39.73	0
13.73	0	44.96	1	5702.36	4	43.23	0
15.34	0	49.75	2	05.18	1, h	49.47	0, d
16.47	2	53.78	1	11.25	0	50.52	1
17.33	2	56.51	3	12.87	5	52.00	0
18.85	6	59.75	12	14.24	2	64.63	2
19.10	0, h	69.02	4	15.89	1	67.35	1
20.11	1	70.70	2	18.97	1	74.38	1
21.08	1	72.26	1	23.07	2	75.78	1
24.69	1	76.59	0	24.81	4	80.96	0
27.61	10	78.36	8	25.73	4	86.61	1
29.93	0	78.67	3	29.27	0	87.16	2
30.90	1	79.42	3	29.97	3	87.69	2
33.63	1, d?	81.82	0	30.61	3	88.38	1
36.63	1	83.04	1	31.30	0	88.77	2, h
39.19	5	85.39	1	32.93	1	91.97	2
39.40	4	87.43	1, h	34.13	0	93.63	2
40.18	2	90.39	0	34.43	1	94.74	2
44.63	1	5595.19	1	35.53	0	96.50	1
48.47	1	5600.53	3	36.99	1	96.90	1
49.45	1, +g?	03.14	4	37.43	0	5898.85	1
50.07	0	03.56	5	40.55	2	5901.20	2
52.71	4	06.74	5	41.73	0	02.30	1
53.39	1	07.72	1	45.61	2	03.50	0
53.96	1	09.15	3	45.99	5	04.43	3
54.25	0	11.39	1	47.48	6	07.61	0
54.82	10	13.59	1	52.02	4	08.61	0
56.13	8	14.28	0	53.62	2	14.24	3
58.90	1	19.36	1	56.19	1	15.55	1
61.92	1	25.06	2	56.83	4	19.33	9
63.15	1	27.51	4	58.72	2	21.17	0
68.19	0	29.79	3	60.22	0	21.37	12
72.84	2	31.58	2	62.35	2	24.36	1
73.67	1	33.56	2	63.64	2	25.25	0
75.15	3	36.23	35	66.10	1	26.85	5
76.34	2, +g, Ag	36.70	1	66.88	1	27.38	0
79.41	9	38.73	1	67.91	5	28.36	1
80.31	8	41.66	3	69.88	0	29.26	1
81.12	0	45.04	0	71.20	2	29.62	0
82.16	1	45.74	0	74.38	4	32.37	6
83.24	2	47.57	2	74.86	1	36.68	4
84.33	10	47.87	3	76.85	1	38.58	1
84.66	4	49.55	3	79.94	1	43.74	1
85.11	1	50.81	2	82.36	3	44.40	3
85.73	2	52.80	0	82.57	5	46.81	0
90.55	2	53.30	3	83.71	2	48.90	0
90.78	0	55.64	0	84.08	2	51.14	4
94.37	3	56.64	1	84.78	0	53.38	1
95.78	0	56.96	3	90.57	2	63.50	1
96.70	5	58.43	2	92.22	2	69.34	3
97.84	0, h	63.06	1	5798.84	1	70.54	2
99.02	1	65.20	3	5800.02	1	73.44	9
5499.66	2	69.27	0	02.00	2	74.16	3
5501.04	5	70.50	1	04.38	6	78.07	0
01.86	1	71.91	1	07.93	4, h	80.65	1
02.20	0	74.84	1	10.14	0	82.25	1
06.95	2	76.55	2	10.86	1	84.92	1
5510.72	15	5677.08	0	5813.01	1	5986.70	1

TABLE 1.—*Arc spectrum of ruthenium*—Continued

λ I. A.	Intensity and notes	λ I. A.	Intensity and notes	λ I. A.	Intensity and notes	λ I. A.	Intensity and notes
5988.67	5	6241.59	1	6556.22	1	6883.50	1
89.60	0	52.06	4	57.85	1	85.69	2
91.28	1	55.34	1	59.48	2	91.91	2
92.57	1	57.99	1	60.46	4	6895.20	0,h
93.65	6	59.66	0	61.46	0	6002.26	2
5999.63	0	70.09	1	69.10	2	04.57	0
6002.88	0	74.56	1	77.99	1	09.79	1
03.87	2	84.52	3	93.75	3	11.47	8
04.46	1	85.77	1	96.60	2	13.79	1
06.96	0	89.35	1	6599.37	1	18.53	3
09.10	2	90.17	2	6605.90	0	22.00	1
12.83	2	6295.22	5	13.12	2	23.22	12
21.83	2	6303.22	2	18.20	4	26.70	1
22.30	3	04.12	3	20.41	1	28.71	0
26.33	1	04.50	1	33.40	1	34.81	3
27.52	3	06.81	1	35.28	3	38.14	2
29.14	3	07.59	0	40.90	2	52.10	0
33.34	2	09.70	3	49.56	2	58.36	1
37.73	1	10.38	0	51.48	2	58.85	1
38.76	1	11.16	2	58.84	1	60.80	2
46.44	3	16.74	4	63.16	9	81.99	10
54.07	2	24.25	2	64.11	2	95.48	1
57.50	1	30.63	5	66.49	1,h	6998.23	1
65.18	2	31.57	0	67.73	1	7000.01	0,h
71.18	0	32.01	0	69.73	2	01.68	3
73.92	1	36.09	3	76.60	1	12.92	1
78.26	2	43.05	2	88.20	0	16.10	1
80.15	4	48.39	1	6690.00	15	17.43	1
82.31	1	51.89	2	6702.07	3	27.93	10
83.54	3	57.90	5	18.27	6	33.16	0
85.13	2	63.41	4	21.81	2	34.42	2
89.45	1	71.27	1	24.76	0	35.82	0
90.58	6	76.43	5	30.42	5	53.06	1, h
6096.94	0	82.99	4	31.79	3	54.82	0
6101.54	1	84.65	4	33.96	2	57.13	2
03.68	3, h	88.06	3	38.09	1	58.42	2
08.99	2	6390.22	5	42.94	2	60.34	4
15.02	1	6401.43	2	51.75	2	61.17	5
16.76	5	04.85	0	56.53	5	70.15	1
19.87	3	06.07	2	60.86	1	80.31	0
21.05	0	13.30	0	66.92	8	83.69	1
22.40	2	17.57	7	70.10	1	86.03	5
37.70	1	23.96	1	75.00	6	7087.32	5
41.58	3	29.56	2	79.15	1	7103.42	0
50.10	1	32.11	1	87.20	4	10.56	3
70.60	5	39.05	1	89.68	1	20.62	1, h
73.19	2	40.34	2	6792.96	1	26.81	4
74.26	2	44.81	9	6805.08	0	35.20	1
76.78	4	45.85	0	05.52	2	35.63	2
77.76	1	51.86	1	07.03	0	40.82	1
79.99	1	56.90	1	12.90	1,h	41.70	3
85.89	1	57.44	2	13.51	4	46.41	0
89.47	3	61.19	1	17.26	0,h	48.21	0, Ca?
92.58	5	64.29	2	21.73	0	54.16	3
95.40	2	72.54	2	24.06	10	65.83	0, h
95.96	1	77.94	2	31.49	4	67.80	2
97.18	1	82.25	1	36.05	1	68.38	0
6199.42	5	84.50	2	37.09	0	75.70	0
6210.33	1	86.65	3	38.01	2	78.94	0
10.75	3	92.35	1	41.02	0,h	82.20	1
13.66	1	96.44	6	41.57	0	83.00	3
17.48	2	6499.75	0	43.13	0	7194.47	3
19.55	1	6506.27	0	43.86	0	7205.78	0
25.23	5	09.60	0	50.86	2	12.57	1
25.60	1	19.07	3	52.92	0	19.26	5
31.84	3	20.89	1	58.75	1	25.32	1
32.20	0	28.75	5	63.33	0	26.36	0
33.76	1	31.60	0	67.19	1	29.83	1
35.70	4	40.24	4	72.92	3	33.98	1
6235.94	0	6544.27	3	6879.34	0	7236.53	1

TABLE 1.—*Arc spectrum of ruthenium*—Continued

λ I. A.	Intensity and notes	λ I. A.	Intensity and notes	λ I. A.	Intensity and notes	λ I. A.	Intensity and notes
7238. 95	9	7449. 68	1	7690. 50	0	7917. 58	0
40. 28	2	50. 67	2	94. 57	0	19. 68	0
49. 07	1	53. 65	3	7697. 47	1	22. 96	2
66. 88	3	58. 43	1	7701. 39	1	24. 46	5
67. 74	1	63. 68	1	19. 26	1	48. 15	3
72. 26	1	65. 76	1	20. 48	1	54. 27	0
7297. 06	2	68. 92	7	22. 86	6	63. 81	0
7306. 36	0	75. 38	4	29. 92	1	67. 89	3
12. 65	2	85. 80	8	39. 77	0	7999. 74	1
15. 66	2	95. 18	0, Rh?	59. 67	1	8006. 30	0
18. 76	1	7499. 78	10	70. 93	0	17. 69	2
19. 77	0	7503. 10	0	81. 37	1	36. 67	2
22. 04	1	19. 59	2	91. 87	8	8074. 30	0
23. 56	5	26. 42	1	7797. 92	2	8112. 50	3
26. 22	0	29. 59	4	7806. 79	3	48. 38	1
29. 80	1	32. 08	4	09. 18	0	57. 67	1
38. 86	2	40. 83	0	13. 51	1	68. 78	1
41. 47	2	41. 70	1	15. 41	0	73. 90	1
41. 82	0	44. 20	1	29. 84	2	81. 97	1
42. 34	0	49. 87	0	30. 52	0	8194. 66	0
48. 70	3	54. 31	2	33. 40	2	8220. 41	2
51. 88	2	59. 62	8	34. 79	1	39. 15	0
74. 41	0,h	69. 26	0	41. 96	3	60. 14	0
77. 74	3	75. 08	1	47. 82	7	64. 95	4
81. 04	2	7581. 36	0	53. 78	1	8281. 89	1
91. 33	0	7609. 00	1	71. 94	0	8348. 99	2
7393. 92	8	11. 59	0	76. 78	1	8352. 95	2
7401. 24	0	12. 99	3	81. 48	10	8400. 58	0
07. 52	1	16. 80	1	90. 39	5	35. 76	1
10. 27	2	21. 52	6	7893. 29	0	48. 57	0
10. 66	1	47. 41	1	7900. 17	1	73. 64	2
19. 61	1	58. 45	2	04. 15	0	8483. 56	2
30. 75	2	60. 36	1	05. 16	0	8710. 76	2
38. 35	1	77. 47	2	06. 15	1	24. 98	1
7445. 47	2	7687. 48	2	7908. 75	0	8777. 27	0
						8867. 84	0

TABLE 1*a*.—*Corrections to ruthenium tables*

Kayser	Exner and Haschek	Eder and Valenta	Suggested corrections	Kayser	Exner and Haschek	Eder and Valenta	Suggested corrections
4542. 68 (1)	----------	----------	----------	5471. 55 (0)	----------	----------	5471. 55 Ag (10)
49. 93 (3)	----------	----------	----------	5582. 28 (2)	----------	----------	----------
59. 04 (1)	----------	----------	----------	----------	----------	5840. 04 (2)	5840. 12 Pt (15)
4589. 00 (0)	----------	----------	----------	----------	----------	74. 64 (1)	----------
4646. 15 (0)	----------	----------	4646.16 Cr (12)	----------	----------	5894. 01 (2)	5894. 06 Ir (15)
4652. 19 (0)	4652. 17 (1u)	----------	4652. 16 Cr (9)	----------	----------	5941. 45 (1)	----------
4714. 16 (0)	----------	----------	----------	----------	----------	6246. 31 (1)	6246. 34 Fe (5)
33. 31 (0)	----------	----------	----------	----------	----------	6318. 06 (1)	6318. 03 Fe (6)
----------	4736. 88 (1u)	----------	4736. 79 Fe (5)	----------	6332. 29 (1u)	----------	----------
53. 10 (0)	53. 08 (1u)	----------	----------	----------	----------	45. 92 (1)	----------
----------	62. 38 (1)	----------	4762. 38 Mn (8)	----------	----------	54. 49 (1)	----------
----------	4762. 59 (1)	----------	----------	----------	----------	55. 08 (1)	55. 04 Fe (3)
4895. 38 (1)	4895. 35 (2)	----------	----------	----------	----------	93. 55 (2)	93. 61 Fe (5)
----------	4934. 08 (3)	----------	4934. 10 Ba (10)	----------	----------	6396. 32 (1)	----------
5077. 06 (1)	----------	----------	5076. 07 Ru (5)	----------	----------	6400. 01 (3)	6400. 02 Fe (6)
5077. 30 (3)	----------	----------	5076. 34 Ru (7)	----------	----------	6471. 26 (1)	----------
----------	5165. 0 (1u, b)	----------	----------	----------	----------	6496. 86 (2)	6496. 91 Ba (10)
5169. 07 (0)	----------	----------	5169. 03 Fe (4)	----------	----------	6505. 40 (1)	----------
5176. 19 (0)	----------	----------	----------	----------	----------	6564. 05 (1)	6564. 05 Sb (5)
5209. 50 (2)	5209. 48 (1)	----------	----------	----------	----------	6648. 10 (1)	6648. 13 Sb (4)
5362. 08 (2)	5362. 06 (1)	----------	----------	----------	----------	6692. 82 (1)	----------

2. RHODIUM (Rh=102.9; Z=45)

In Kayser's table of the arc spectrum of rhodium 183 lines are given between 4503 and 5983A. His rhodium salts contained only traces of osmium. Eder and Valenta give only 48 values limited by 5792 and 6965A. The tables of Exner and Haschek contain 196 lines from 4504 to 6966A after they subtracted Cu, Ir, Pd, and Pt impurities. Table 2 contains 572 lines with wave lengths ranging from 4503 to 8615A, while extra lines given by other observers are collected in Table 2*a*, together with suggested corrections for some of them.

TABLE 2.—*Arc spectrum of rhodium*

λ I. A.	Intensity and notes	λ I. A.	Intensity and notes	λ I. A.	Intensity and notes	λ I. A.	Intensity and notes
4503.80	10	4653.33	2	4840.12	1	5059.92	1
06.66	3	57.57	1, h	42.40	8	64.32	5
15.17	1	62.52	0	43.99	15	70.98	1
23.10	1, Pt?	64.99	2	47.27	0	85.52	5
23.54	1	65.17	1	51.63	20	88.78	2
25.21	3	66.12	2	52.65	1	5090.63	10
27.52	1	75.03	20	61.33	4, h	5103.18	1
28.74	20	77.40	6	61.64	1	08.19	1, h
30.60	3	82.95	6	63.17	0	09.97	3
34.36	1	83.67	1	65.77	5	20.69	5
36.74	2	89.47	3	66.75	2	30.76	5
37.68	1, h	96.32	2	76.19	2	33.68	1
42.34	0	4699.86	1	78.03	1, h	43.11	1
44.27	7	4700.72	2	87.92	2	44.97	4
45.29	1	04.08	10	96.23	1	53.34	2, Cu?
48.73	9	05.75	0	4897.88	3	55.54	10
51.65	10	06.94	3	4903.09	1, Ru?	57.09	8
52.23	1	09.27	2	06.36	0	58.69	9
54.08	0	19.40	3	08.60	4	60.35	2
56.25	1	19.76	0	13.52	3	64.10	2
57.19	4	21.01	8	14.74	0	64.70	1
58.72	6	24.34	3	18.81	4	65.41	5
60.46	1	31.19	4	19.69	5	66.87	0, h
60.88	8	39.22	3	22.51	5	74.71	2
65.18	7	45.11	15	24.30	1	75.96	12
66.21	1	47.57	1	24.70	1	77.25	6
68.40	2	50.81	1, h	25.18	1	78.17	3
69.01	15	53.79	1, h	27.00	0	83.81	0
70.31	3	55.57	6	30.79	1	84.20	9
71.29	6	68.11	3, h	44.84	5	85.02	3
72.64	4	70.80	4	58.42	1	86.93	1
76.01	1, H	71.55	3	60.18	2	93.13	30
78.01	1, H	77.17	5	61.12	2, h	5197.55	2
83.14	1	78.51	1	63.69	10	5202.57	1
90.91	1	82.60	1, h	66.38	5	03.32	3
91.24	2	88.12	0, Pd?	77.74	10	06.95	5
95.60	3	91.01	6	79.15	9	11.49	5
4599.40	2	91.48	2	80.41	1	12.73	4
4601.65	3	92.62	0	84.97	5	13.36	2
08.14	10	94.18	2	85.34	2	14.78	5
10.69	2	4798.67	5	88.20	1	22.65	8
11.46	2, h	4801.35	3	95.87	3	23.61	1
16.28	1	01.69	1	4997.78	3	25.58	4
19.91	9	03.22	2	5012.39	3	27.84	0
25.96	3	07.57	1	22.04	1	28.43	1
30.00	2	10.47	12	25.58	4	30.61	9
33.88	4	13.40	2	26.30	1	31.13	2
39.38	7	17.07	2	28.34	5	32.51	1
43.19	10	33.47	2	46.43	3	37.14	12
4648.44	0	4836.87	1	5057.42	3	5237.78	6

TABLE 2.—*Arc spectrum of rhodium*—Continued

λ I. A.	Intensity and notes	λ I. A.	Intensity and notes	λ I. A.	Intensity and notes	λ I. A.	Intensity and notes
5248.74	2	5553.20	1	5908.19	2	6414.70	8
51.41	7	55.08	2	12.00	0	18.60	2
59.25	7	56.77	4	18.53	5	31.24	3
61.95	2	57.17	3	23.73	2	45.15	2
67.93	3	61.23	0	26.94	0	52.72	2
69.28	10	61.90	1	30.91	1	56.63	0
77.94	1	65.00	1	41.48	6	62.02	1
80.10	7	68.31	2	52.46	4	79.91	1
85.80	1, h	75.23	1	60.81	0	85.62	4
92.14	10	77.02	0	70.69	2	6499.49	0
5295.06	2, H	82.62	1	83.56	10	6510.38	10
5302.44	1	86.51	1	86.83	0	11.22	0
11.05	2	88.20	1	91.16	5	17.56	4
13.27	1	94.87	5	95.46	1	19.70	15
14.76	9	97.20	1	5997.13	0	6592.04	1
25.78	0	5599.43	40	6006.45	0	6618.52	1
26.94	1	5601.54	2	18.14	1	19.49	1
29.43	5	07.72	5	27.91	1	27.80	8
29.74	15	08.35	8	43.85	1, n, l	30.13	15
31.06	6	16.20	1	57.18	1	32.13	3
36.61	4	17.88	1, h	72.96	2	37.34	1
39.65	2	26.07	4	6087.36	3	43.68	1
40.69	1	29.47	0	6102.70	10	45.01	2
49.30	7	32.77	4	16.14	5	58.78	0
51.09	1	34.66	3	18.00	0	59.10	1
54.38	50	51.29	3	18.86	3	63.07	0
56.45	8	53.92	0	28.04	6	73.23	1
61.82	1, Ru?	54.51	0	32.17	0	6686.65	2
64.07	3	59.62	6	38.29	1	6705.38	1
69.27	4	60.74	4	44.33	3	16.69	1
79.08	30	65.82	1, h	47.70	2, h, l, n?	21.33	2
81.48	3	69.20	1, H	54.14	0	25.40	1
84.00	2	86.36	15	57.79	1	30.80	1
90.44	20	5695.65	2	58.87	2	52.38	20
5396.42	1	5702.46	8	65.48	0	53.29	0
5404.69	15	08.74	2	65.75	1	62.91	1
08.72	3	10.36	1, h	73.89	6	85.37	2
13.83	2	13.65	2	77.90	0	6796.65	8
15.39	1	16.31	1, H	78.85	0	6827.33	6
23.28	6	20.48	1	80.36	3	29.33	4
24.05	18	26.69	3	84.29	1	37.80	2
24.71	8	27.30	4	86.89	7	43.51	4
25.44	10	30.42	3	92.60	1	57.68	5
31.60	2	42.37	1, h	97.06	1	68.57	0
32.04	3	55.72	2	6199.99	9	74.54	1
39.58	6	57.34	0	6219.57	4	77.18	1
41.34	8	75.30	0	42.39	1	77.85	1
44.29	7	78.48	0	49.93	4	79.94	10
45.21	12	82.13	0	53.69	8	92.14	0
59.29	1	86.84	1	58.95	4	6898.22	1
68.10	5	92.66	8	76.64	4	6905.39	0
68.72	2	95.77	5	77.43	6	11.79	2
70.85	5+g, Ag	5797.50	3	78.08	3	19.02	3
73.59	0	5801.00	0	79.60	1	25.49	2
76.13	4	03.33	6	80.67	2	51.14	1
79.81	2	06.87	15	83.02	1	65.65	10
81.41	5	16.01	2	87.37	3	72.91	4
84.24	8	21.82	4	90.39	3	79.13	7
91.86	4	30.35	1	93.36	5	6994.64	2
93.97	0	31.59	10	6294.17	2	7001.54	7
5496.97	3	33.61	2	6307.18	5	09.40	1
5503.59	4	53.34	1	19.51	9	7038.73	5
04.15	1	56.86	1	32.98	7	7101.68	10
04.66	6	71.77	3	42.18	0	04.47	9
28.24	0	74.99	0	63.77	2	41.34	1
33.87	3	77.58	1	77.00	2	42.56	3
35.02	15	91.20	1	6386.56	4	51.85	0
42.06	2	97.37	2	6402.31	2	66.19	2
42.98	2, H	5898.94	2	10.21	3	87.04	3
5544.62	15	5907.33	5	6413.00	6	7199.52	0

TABLE 2.—*Arc spectrum of rhodium*—Continued

λ I. A.	Intensity and notes	λ I. A.	Intensity and notes	λ I. A.	Intensity and notes	λ I. A.	Intensity and notes
7219. 06	4	7430. 81	4	7690. 65	7	8063. 50	2
27. 72	2	42. 41	8	7707. 93	2	8077. 77	0, d?
40. 36	2	46. 78	3	36. 91	1	8136. 20	4
56. 50	1, h	49. 35	1	69. 84	1	59. 88	0
62. 62	2	53. 45	0	72. 90	7	66. 94	0
68. 23	7	72. 36	0?	7791. 61	9	73. 41	0
70. 82	10	75. 74	10	7824. 91	10	8193. 63	2
71. 94	5	92. 64	3	30. 05	6	8210. 49	1
73. 06	3	95. 22	10	46. 50	4	8321. 58	0?
73. 61	0	7496. 93	2	47. 73	0	69. 55	1
82. 82	2	7510. 97	0	71. 54	0?	8389. 71	0
85. 23	0?	13. 97	3	7899. 55	0?	8425. 51	2
90. 53	1	24. 29	1	7981. 99	2	8615. 23	0
93. 20	2	42. 02	5	8006. 34	0		
7299. 82	2	49. 54	1	16. 59	2		
7314. 93	0	57. 67	6	29. 91	6		
30. 11	1	77. 22	6	36. 11	4		
75. 56	5	7579. 54	2	43. 92	2		
7386. 61	3	7639. 20	1	45. 40	7		
7423. 68	2	7641. 19	0	8053. 31	0		

TABLE 2*a*.—*Corrections to rhodium tables*

Kayser	Exner and Haschek	Eder and Valenta	Suggested corrections	Kayser	Exner and Haschek	Eder and Valenta	Suggested corrections
4749.83 (0)	....	....	....	6475.11 (2u)	....	....	5476.13 Rh (4)
4856.43 (0)	....	....	....	5480.79 (0)	....	....	5479.81 Rh (2)
....	4934.05 (1)	....	4934.10 Ba(10)	5604.99 (0)	....	....	....
4960.83 (0)	4960.92 (1u)	....	....	5659.70 (2u)	....	....	5660.74 Rh (4)
5073.43 (0)	5073.45 (1)	....	....	5700.41 (4u)	....	....	5702.46 Rh (8)
....	5086.82 (1)	....	....	17.82 (0)	....	....	5717.88 Fe (4)
....	5105.50 (4)	....	5105.56 Cu (8) Fe(5)	5742.76 (0)	5742.77 (1)	....	....
5157.64 (5)	....	....	5158.69 Rh(9)	....	....	6162.04 (1)	6162.19 Ca(10)
....	5165.06 (2)	....	....	....	....	6245.31 (1)	....
....	5269.51 (2)	....	5269.53 Fe (6)	....	6332.29 (1u)	....	....
....	5328.00 (1)	....	5328.06 Fe (6)	....	....	6430.84 (1)	6430.86 Fe (5)
5359.66 (0)	....	....	5359.69 K (5)	....	....	6707.72 (2)	6707.85 Li (20)

3. PALLADIUM (Pd=106.7; Z=46)

Of the six elements in the group of platinum metals palladium has the smallest number of lines in its arc spectrum, but a larger proportion are of higher intensity than in the other spectra. Kayser used Heräus metal containing only a trace of Pt and gave 70 lines of wave lengths from 4516 to 5760A while Eder and Valenta added 12 lines, the longest being at 7016A. Exner and Haschek used metal from Heräus and the following impurities were detected in the spectrum: Ag, Ba, Bi, Ca, Cd, Cu, Mn, Pb, Pt, Rh, Sn, Zn. Their table of palladium arc lines contains 75 lines with wave lengths between 4516 and 6784A. The wave lengths for 172 lines from 4497 to 9234A are shown in Table 3, and in Table 3*a* a small list of lines whose palladium origin may be doubted is added.

TABLE 3.—*Arc spectrum of palladium*

λ I. A.	Intensity and notes	λ I. A.	Intensity and notes	λ I. A.	Intensity and notes	λ I. A.	Intensity and notes
4497.66	3	5179.31	0	5690.14	8	6784.52	50
4516.20	10	5208.93	10	5695.08	20	6833.42	8
22.33	1	20.06	0	5730.52	0	56.89	0
41.13	10	34.85	20	36.62	12	78.35	2
52.91	4	38.41	2	37.65	4	6892.52	0
59.83	1	56.17	10	39.68	7	6914.98	2, h
4589.99	4	94.15	7	59.92	4	16.56	9
4631.37	2, h	5295.61	50	78.85	1	6917.56	2
32.63	3	5211.50	1	5782.14	3	7016.44	8
64.54	0	12.57	12	5868.14	2	26.91	1
4677.46	8	45.10	10	5974.03	0	37.58	3
4700.12	1	46.79	2	78.96	0	52.04	2
08.06	2	61.72	2, h, v	5995.94	0, Os?	7060.29	5
22.75	1	62.69	15	6064.08	1	7115.84	3
24.01	6	63.26	4	6101.65	0	7149.11	6
61.88	3	77.62	3	29.45	0	7228.99	1
71.37	0	85.44	2	30.59	8	42.90	2
76.56	4	94.76	6	36.99	1	7278.44	2
88.18	20	5395.26	25	70.94	5	7310.06	5
90.85	2	5406.59	5	76.15	5	68.14	15
4799.02	1	27.69	4	88.02	6	7391.91	8
4806.37	1	35.16	7	6195.61	2	7486.93	7
14.65	1	59.16	2	6203.13	0	7763.99	12
16.27	1	72.67	1	03.73	0	7786.66	7
17.02	9	5496.85	6	43.97	2	7915.84	7
17.51	30	5529.45	9	44.78	1	7961.04	4
19.15	2	41.88	1	6268.23	0	8132.85	6
36.44	4	42.80	30	6342.46	1	8300.81	5
4875.43	20	47.02	20	6444.89	2	8353.54	2
4919.87	8	5562.70	3	6464.68	0	8451.93	0
24.20	2	5600.62	2, h	6465.90	0	8532.67	2
29.99	3	01.65	8	6508.41	6	81.99	2
4971.95	9	02.29	2	91.44	3	85.28	1
5063.40	10	03.00	4	97.08	1	8599.06	2
5092.53	0	08.02	7	6599.32	0		
						8644.38	1
5101.57	3	19.46	12	6603.03	1	8695.03	1
05.56	5, +Cu?	21.33	3	23.26	4	8761.34	2
07.43	1	42.71	8	25.28	4	9234.02	1
10.81	15	55.42	10	62.80	4		
14.38	8	68.42	3	81.53	3		
17.01	20	70.06	30	85.71	2		
27.71	7	74.25	3	6686.79	3		
57.56	0	77.07	1	6712.10	0		
61.36	5	80.80	2	39.16	0		
5163.83	40	5687.49	3	6774.54	12		

TABLE 3*a*.—*Corrections to palladium tables*

Kayser	Exner and Haschek	Eder and Valenta	Suggested corrections	Kayser	Exner and Haschek	Eder and Valenta	Suggested corrections
4822.17 (0)	4822.28 (1u)	----------	----------	5548.29 (2u)	5548.33 (1u)	----------	----------
4918.83 (3)	----------	----------	4919.87 Pd(8)	----------	5658.87 (1u)	----------	5658.84 Fe(6)
5427.21 (1)	----------	----------	----------	5664.36 (1)	----------	----------	----------
----------	5465.52 (2)	----------	5465.49 Ag(30)	5700.76 (0)	----------	----------	----------

4. OSMIUM (Os=190.9; Z=76)

Analogous to iron and ruthenium, which exhibit the most complex spectra in their respective triads, osmium has the richest spectrum of any metal in the third triad, but the longer waves have been less completely described for osmium than for any of the other elements.

Kayser gives 35 lines of wave length above 4503, but none greater than 5728A. The osmium salt at his disposal contained a large amount of Ir, and traces of Pt and Ru. Eder and Valenta were not very successful in photographing the yellow and red of this spectrum; between 5523 and 6162A they give 15 lines, but 3 of these are of doubtful origin. Exner and Haschek used Heräus metal alloyed with zinc and containing Pt and Ru impurities. Their table of osmium lines contains 102 lines with wave lengths between 4500 and 6402A. In Table 4 new results are given for 942 lines in the arc spectrum of osmium from 4500 to 8644A, and in Table 4*a* lines of doubtful origin are brought together.

TABLE 4.—*Arc spectrum of osmium*

λ I. A.	Intensity and notes	λ I. A.	Intensity and notes	λ I. A.	Intensity and notes	λ I. A.	Intensity and notes
4500.74	3	4590.93	3	4671.54	0	4775.21	1
04.04	2	94.08	1	74.01	2	75.83	1
05.69	0	95.02	7	75.87	1	77.60	0
06.31	1	97.14	6	80.04	1, d	78.93	2
09.12	1, d	4597.87	2	81.43	2	81.51	2
10.12	2	4601.59	1	82.31	4	83.53	2
12.61	1	05.02	3	84.18	0	93.99	15
14.91	3	05.58	1	84.59	1	4797.21	0
16.72	0	06.12	1	84.98	1	4800.24	1
17.33	0	08.28	3	86.50	2	02.08	1
18.89	4	10.81	1	87.39	0	04.33	1,d
19.87	3	13.59	2	91.76	2, h	05.29	1
20.33	5	14.18	1	4692.05	6	07.11	2
23.22	1	15.26	0	4702.73	2	10.74	1
24.86	6	15.66	1	03.59	1	12.62	2
29.67	7	16.78	10	04.05	1d,Rh?	13.79	4
30.53	1	18.00	0	04.85	2	14.04	1,h
36.84	1	18.56	0	05.94	2	15.48	3
37.62	4	23.03	1	10.02	2	15.95	6
39.92	6	23.27	1	13.86	1, d	16.53	1
41.50	1	28.61	3	15.02	2	17.39	0
43.67	1	29.05	2	17.21	1	21.65	1
44.15	0	29.37	2	18.99	3	23.46	2
45.80	3	31.83	10	19.60	2	26.65	4
47.09	1	33.18	2	21.27	4	28.44	2
47.89	1, d	34.76	4	24.37	1	30.00	2
48.67	7	37.58	1	28.79	0,Ir?	34.61	2
50.39	10	38.62	4	32.78	4	38.12	2
51.28	8	39.73	1	33.74	2	40.60	0
52.87	0	40.63	0	34.40	3	43.87	5
55.52	0	41.83	4	35.03	1	45.00	0
55.65	1	42.27	1, d	35.92	1	49.21	3
61.19	1	44.58	1	38.04	4	51.89	2
62.60	2	47.30	2	38.39	5	52.57	2
64.44	1	48.01	0	39.60	1	54.94	2
66.33	1	50.58	1	42.59	2	58.47	2
66.51	3	52.86	1	43.88	5	58.78	1
67.47	2	55.22	2	44.67	1	59.48	2
70.51	2	55.48	1	48.46	2	64.03	3
72.93	2	57.24	3	51.07	0	65.61	10
75.68	0	57.81	1	52.15	5	67.17	3
77.21	0	58.54	2	55.16	2	68.83	1,d
77.94	1	59.48	1	57.55	2	73.11	2
79.05	5	61.02	1	60.14	2	76.09	1
80.32	1	61.63	1	60.78	3	77.34	2
80.77	1	63.83	8	63.09	5	78.52	4
83.70	1	67.54	2	65.51	0	82.29	3
84.95	2	68.20	1	70.84	1	83.82	1
87.25	1	68.93	1	71.77	1	85.07	1
4588.59	2	4670.69	2	4772.83	1	4889.32	2

TABLE 4.—*Arc spectrum of osmium*—Continued

λ I. A.	Intensity and notes	λ I. A.	Intensity and notes	λ I. A.	Intensity and notes	λ I. A.	Intensity and notes
4892.50	1	5039.11	5	5176.62	0	5364.23	1
92.93	0	39.76	1	80.24	1	66.04	1
95.27	3	42.19	3	82.28	2	74.54	1
95.96	2	45.09	0	85.99	0	75.12	2
4899.22	7	47.16	2	86.42	1	76.80	7
4902.18	2	48.33	1	88.41	1, d	79.31	3
06.49	1	49.10	1	93.52	5, +g, Ag	81.72	0
08.83	0	50.42	2	5199.27	1	85.70	3
09.84	1	52.36	1	5202.63	9	86.92	2
10.48	2	53.99	1	03.23	3	87.14	2
12.60	6	56.01	2	24.02	1	89.27	1
21.80	3	56.73	1	26.58	2	91.47	2
25.43	2	59.40	1,Pt?	31.43	1	91.92	2
26.39	2	63.46	1, Pd?	32.87	2	95.05	0
28.96	0	65.43	0	33.27	2	5395.57	0
31.26	1	71.11	1	36.16	1	5400.66	1
33.45	1	72.88	4	40.91	1	02.71	1
35.82	4	74.80	4	41.16	2	03.44	3
40.21	2	76.30	2	41.79	1	06.88	1
40.85	1	76.99	2	44.85	1	09.33	1
41.76	0	77.59	2	46.24	0	12.15	3
42.95	4	79.09	4	49.68	1	16.33	10
45.48	1	80.75	0	50.46	3	16.67	5
49.56	0	81.29	1	51.82	0	17.17	1
50.59	2	86.24	0	52.53	1	17.51	4
51.90	1	86.55	1	54.17	1	19.70	2
53.86	1	86.83	0	54.99	2	26.56	1
55.73	2	93.11	2	55.82	5	32.40	1
58.17	2	93.78	0,Ru?	56.22	1, Pd?	33.01	1
59.04	2	96.17	0	59.80	2	33.46	0
63.86	0	5099.53	0,h	60.12	1	33.87	0
65.47	1	5100.62	0,h	60.63	1	36.82	1
68.91	3	03.49	7	61.94	1	37.76	1
70.67	0	04.73	3	65.13	6	39.78	0
71.67	1	07.35	1	68.47	2	41.10	2
75.04	1	08.25	2	71.84	2	41.81	4
76.02	1	09.87	2	77.21	1	42.08	2
76.43	0	10.82	5,+Pd?	80.70	2	42.92	1
76.78	0	11.51	0,h	81.48	0	43.31	7
77.91	1	18.59	1	83.90	3	43.79	1
78.90	1	19.95	1	84.78	1	45.77	0
79.31	4	20.75	1	86.03	0	46.93	4
82.89	3	22.23	3	87.67	3	47.75	3
87.03	1	23.37	2	88.73	1	49.36	4
90.12	3	24.35	3	89.64	0	52.29	1
92.02	0	27.94	1	95.66	3, Pd?	53.39	4
93.84	0	28.98	1	96.46	1	55.30	1
97.60	1	29.44	1	5298.78	5	57.30	4
4999.27	0	31.92	1	5302.57	3	58.88	1
5000.50	1	34.90	3	03.65	1	62.76	1
06.60	1	35.91	2	08.18	1	67.76	1
09.68	1	36.61	1	11.54	1	70.00	4
11.01	0	37.88	1, h	12.40	1	74.57	2
12.50	3	43.28	2	35.36	1	75.11	2
15.09	;0,Ir?	45.57	4	36.22	4	77.24	2
16.50	0	46.49	2	37.87	1	79.18	1
16.88	0	46.86	2	39.59	1	79.99	1
17.50	1	49.73	7	40.16	0	81.83	4, +g, Ag
17.97	1	51.00	1	41.32	1	85.06	0
19.65	3	52.01	5	42.30	0	89.10	0
20.64	1	54.28	0	45.08	2, Pd?	89.63	1
20.91	3	56.41	2	46.02	3	91.24	2
21.32	1	57.51	3	48.32	1	5493.52	1
21.70	1	59.29	1	50.83	0	5504.86	1
23.04	2	63.26	2	52.26	3	07.15	1
23.77	1	64.97	1	53.63	1	07.33	1
26.05	1,h	68.98	3	55.29	1	09.33	5
29.24	2	70.92	1	56.34	0	11.72	1
31.84	6	71.72	3	61.64	1, h	16.01	2
5034.17	3	5174.65	1	5362.88	3	5520.38	0

TABLE 4.—*Arc spectrum of osmium*—Continued

λ I. A.	Intensity and notes	λ I. A.	Intensity and notes	λ I. A.	Intensity and notes	λ I. A.	Intensity and notes
5523.55	30	5711.10	1	5903.23	3	6154.03	4
25.66	1	14.75	2	03.97	5	58.03	7
26.18	1, d?	18.32	1	06.82	4	60.04	1
29.55	2	19.21	2	08.95	4	66.92	2
37.15	2	21.93	20	12.02	2	74.52	1, n? 1
39.08	1	25.85	1	14.28	1	85.3	1, n? 1
42.39	1	26.19	0	17.71	0	6195.81	1
46.82	4	31.09	3	19.61	1	6204.55	0
48.80	3	33,05	0	25.82	0	05.72	1
49.17	1	37.90	3	26.59	0	15.93	2
49.79	4	38.08	1	27.30	1	19.12	0
52.87	4	38.84	0	31.75	0	20.99	0
53.36	0	39.72	4	34.03	2	22.05	0
57.17	3, h	41.10	1	40.31	3	22.85	0
60.62	4	41.36	0	48.53	1	24.81	0
69.05	0	42.23	1	50.68	1	26.50	3
71.42	1	46.97	1	51.41	1	27.74	10
72.01	3	51.49	3	54.86	2	28.91	2
73.05	1	52.63	1	55.74	2	41.71	4
74.48	1	57.46	1	62.01	2	48.87	2
80.20	2	57.94	1	64.81	2, d?	50.47	1
80.66	5	61.21	1	67.38	2	55.28	1
82.10	0	65.05	5	75.17	0	66.68	0
83.69	2	71.03	0	76.32	0	69.45	5
84.43	10	74.98	2, +g	78.25	2	71.42	2
87.22	0	75.35	0	79.39	0	73.45	0
87.73	2	75.99	1	79.78	1	74.97	4
88.96	0	77.40	1	81.36	2	80.74	1
91.87	1	78.33	1	83.22	3	6286.84	4
94.18	1	79.64	1	91.76	2	6303.25	2
5595.07	1	80.81	10	92.95	1	08.07	1
5600.50	3	82.44	2	95.99	10	13.45	1
01.22	0	85.68	1	5998.10	0	20.05	1
04.89	0	90.26	1	6001.16	0	26.76	0
11.96	1	92.54	0	07.19	2	33.01	3
14.53	1	95.92	2	10.22	2	35.59	0
19.42	0,Pd?	96.36	2	15.76	6	37.63	0
20.10	7	96.97	1	16.97	1	40.51	2
23.34	1	5797.86	1	19.81	3	50.12	3
24.74	3,h	5800.58	7	20.83	1	54.64	0
26.42	0	02.17	1	31.03	1	58.39	2
29.82	1	04.27	1	41.46	0	66.55	2
32.06	2	08.70	2	42.02	0	75.57	2
35.08	1	09.94	1	45.35	1	75.82	3
36.12	0,Ru?	19.12	0	50.73	2	78.72	2
37.41	3	20.09	1	52.89	1	82.58	2
37.76	2	21.08	1	54.63	3	83.72	2
42.57	4	22.68	0	56.32	1	92.91	1
45.25	5	30.97	3	57.02	1	93.73	2
45.66	1	42.49	3	58.90	1	6398.87	4
48.98	2	47.80	0	63.88	0	6403.18	8
50.20	2	49.24	1	64.67	0	09.60	3
52.69	1	49.98	1	74.13	2	10.32	1
55.90	0	57.75	15	74.49	1	18.60	2
56.12	1	60.65	6	75.13	0	21.87	1
60.21	3	66.45	0	89.40	1	25.67	2
61.98	0	71.25	2	91.15	2	35.39	1
74.38	3	72.47	0	6092.95	1	40.61	1
75.91	1	73.64	0	6100.83	1	43.96	1
76.88	1,h	76.31	1	03.24	2	45.31	1
78.16	1,h	77.29	1,h	04.32	2	46.00	1
80.91	7	78.48	1	15.94	2	47.68	3
83.91	1	82.89	4	20.38	3	48.13	4
86.61	1	83.81	0	26.52	0	50.50	0
89.09	1	91.58	0	34.56	1	52.59	1
92.32	2,h	94.29	2	40.05	2	61.73	0
95.05	3,Pd?	94.59	3	43.07	1, d?	78.30	3
5698.25	1	96.75	1	43.83	0	80.09	3
5703.64	1	5898.65	0	44.55	6	81.80	1
5709.37	3	5900.99	2	6151.19	2	6482.21	0

TABLE 4.—*Arc spectrum of osmium*—Continued

λ I. A.	Intensity and notes	λ I. A.	Intensity and notes	λ I. A.	Intensity and notes	λ I. A.	Intensity and notes
6491.72	1	6774.74	0	7029.17	2	7500.05	2
6493.57	1	77.86	0	30.11	0	07.20	0
6505.35	0	80.65	1	34.29	2	55.68	1
09.46	2	90.30	2	43.22	1	7565.98	0,h,d?
10.51	2	6791.53	8	51.48	1	7602.96	6
11.34	2	6804.61	2	54.83	3	18.97	3
12.73	1	06.61	7	60.62	6	7673.57	1
16.07	3	39.85	2	67.45	1	7701.46	2
20.85	3	41.79	2	71.35	0	08.27	0
21.20	1	47.62	1	89.86	1	69.94	0
28.88	4	50.60	1	7096.59	1	78.82	0
33.15	4	52.17	1	7104.84	3	90.02	3
38.30	8	75.43	1	08.97	0	96.92	0
39.68	0	78.70	4	11.90	1	7797.82	0
49.65	2	82.82	1	45.50	8	7815.53	1
52.80	2	87.98	2	48.89	6	47.80	0
68.59	2	93.98	1	57.84	2	49.60	0
76.81	6	95.42	1	84.07	3	52.18	3
77.51	1	6898.73	3	89.82	1	7890.34	0
84.49	2	6901.57	4	7199.10	o,h	7901.59	2
89.05	0	03.31	1	7202.10	2	57.16	2
6590.50	3	04.14	1	06.31	5	64.35	0
6606.13	0	07.86	3	09.94	4	74.69	2
14.55	4	09.71	1	11.48	1	81.18	2
15.43	3	22.36	2	24.41	2	7997.12	0
16.56	4	30.90	1	42.06	1	8014.59	1
19.03	2	31.94	1	45.98	1	41.30	3
22.79	0	33.42	1	50.11	1	8055.15	0
39.58	2	45.16	0	51.14	4	8118.07	0
43.64	0	52.52	1	53.52	5	28.95	0
53.65	2, d	54.82	1	7287.85	1,h	32.32	0
59.01	2	55.96	8	7300.70	0,h	57.40	2
61.79	4	66.82	1	12.51	0	78.77	0
63.94	1	71.49	2	17.38	1,h	8194.8	0
65.99	3	75.53	1	38.16	1	8211.76	1
73.12	1	82.37	0	64.06	3	49.62	0
84.50	0	83.78	0	7375.07	3	8263.74	0
88.68	3	84.93	5	7401.31	1	8303.41	1
94.16	1	6997.19	1	03.34	2	8380.26	0
6697.62	2	7002.19	0	07.97	4	8407.9	0
6706.90	1, n, 1	04.94	0	18.67	0	50.22	1
15.83	1	07.01	3	25.20	0	8457.05	0
29.54	9	17.37	2	51.60	0	8514.20	1
30.70	1	20.43	1	56.46	1	8644.8	0
39.60	1h	7024.34	1	7485.28	2		
51.52	2						
58.33	0						
59.42	1						
70.09	2						
6773.00	2						

TABLE 4*a*.—*Corrections to osmium tables*

Kayser	Exner and Haschek	Eder and Valenta	Suggested corrections	Kayser	Exner and Haschek	Eder and Valenta	Suggested corrections
4503.60 (0)	----------	----------	----------	4937.34 (0)	----------	----------	4937.34 Ni (5)
07.42 (0)	----------	----------	----------	----------	5085.85 (1)	----------	5085.83 Cd (10)
----------	4511.32 (1)	----------	4511.3 Cd (5)	5728.52 (2)	----------	5728.53 (1)	----------
4514.27 (0)	----------	----------	----------	----------	----------	6162.40 (2)	6162.19 Ca (10)
----------	4799.95 (1u)	----------	4799.91 Cd (10)	----------	6402.34 (1u)	----------	----------

5. IRIDIUM (Ir=193.1; Z=77)

The table of iridium lines given by Kayser contains 44 lines between 4533 and 5894A. His salts contained considerable Ru and traces of Pt. Eder and Valenta found it impossible to get good exposures in the visible spectrum with metallic iridium without unduly developing the carbon bands. Their table of iridium arc lines has 51 lines within the limits 5620 and 6930A, but some of the lines are admitted to be of doubtful origin. Exner and Haschek used Heräus metal containing Pd, Pt, Rh, Ru, and only 49 lines are ascribed to iridium in the range 4515 to 6334A. Table 5 gives 605 values for wave lengths in the arc spectrum of iridium from 4500 to 8426A, while in Table 5*a* a few lines to be found in the old tables but not in the new are given with corrections.

TABLE 5.—*Arc spectrum of iridium*

λ I. A.	Intensity and notes	λ I. A.	Intensity and notes	λ I. A.	Intensity and notes	λ I. A.	Intensity and notes
4500.97	3	4570.64	3	4662.94	3	4774.50	1
03.30	2	71.42	2	64.67	3	78.16	18
05.08	3	77.18	3	68.98	4	78.99	1
05.72	4	79.34	5	75.53	6	84.63	1
07.19	1	81.91	8	75.88	1	87.75	4
07.68	2	83.93	0	77.33	1	93.18	3
12.04	2	84.76	2	77.62	1	94.66	0,h
15.35	5	85.16	1	78.94	0.h.Fe?	95.26	2
16.11	2	85.59	4	80.45	2	95.67	10
17.01	2	87.44	5	84.10	3	97.04	1
17.37	2	90.94	3	85.06	2	4789.06	0
18.61	0	91.15	1	85.76	0	4802.34	0
21.36	2	94.60	0?	86.43	1	07.14	6
22.22	0	95.35	0, h	89.49	3	09.47	9
23.48	0	96.44	1	94.40	1	10.60	1
25.27	0	4597.93	1	4696.52	0	11.93	0
26.40	1	4602.85	1	4702.58	7	15.10	2
27.01	1	03.84	1	03.15	1	15.39	2
28.44	1	04.47	10	04.06	6	17.56	1,Pd?
29.08	1	11.77	2	05.75	0	19.74	4
32.86	7	12.24	1	06.90	1	20.76	1
35.03	1	14.18	4	08.18	3	26.74	3
36.22	1	16.37	15	08.87	8	40.76	8
36.64	1	16.78	3, Os?	11.85	2	42.98	1
37.39	1	17.38	3	14.72	1	43.24	1
38.67	6	17.65	2	18.12	0	45.37	7
42.89	2	18.05	1	19.34	2	49.75	3
45.69	10	22.14	1	20.93	2	51.39	2
48.50	15	27.10	5	21.88	2	54.99	1
48.85	3	32.66	1	27.61	1	58.00	3
50.25	0	33.14	1	28.04	2	58.97	2
50.77	7	36.05	2	28.86	15	68.41	0
51.77	0, h, Rh?	37.88	3	31.86	8	76.71	1
54.04	3	40.08	9	36.63	1	78.26	1
54.79	2	44.36	3	37.53	1	79.25	1
57.85	3	47.68	0.Ru?	40.28	2	83.62	1
58.74	6	48.24	3	42.27	1	88.50	3
60.89	5	50.10	1	45.84	2	4897.31	1,h
62.94	0	51.08	3	47.07	2	4903.32	3
64.08	2	52.14	2	56.46	10	04.12	2
64.72	0	55.28	1	57.96	8	04.45	4
65.98	0	56.18	9	66.54	3	05.64	3
68.09	12	57.64	4	68.39	3	13.36	2
70.01	9	59.42	2	69.31	3	13.83	3
4570.45	3	4661.99	0	4770.42	2	4920.01	1

TABLE 5.—*Arc spectrum of iridium*—Continued

λ I. A.	Intensity and notes	λ I. A.	Intensity and notes	λ I. A.	Intensity and notes	λ I. A.	Intensity and notes
4924.42	3	5135.49	0	5343.80	2	5609.99	1
27.94	3	43.39	4	49.80	1	10.63	2
31.78	0	46.45	1	56.86	5	18.13	1
33.50	3	46.81	0	57.51	1	20.05	8
34.09	2	50.03	2	60.96	1	22.43	0
35.31	0	52.58	1	64.32	20	25.56	20
38.09	15	58.68	0,Rh?	64.95	6	27.65	3
38.76	2	60.35	0	65.56	1	36.96	0
39.18	6	64.79	2	67.81	0	40.07	1
39.95	2	65.45	1	74.78	2	49.53	3
44.12	0	68.81	1	77.93	0,h	67.24	1
45.34	0	70.97	0,Ru?	82.48	3	70.13	2, Pd?
45.71	1	77.93	8	85.62	7	76.70	1
59.46	2	78.32	1	87.61	1	76.98	2
64.26	1	79.51	0	89.42	0	78.79	3
69.09	2	80.58	2	90.98	7	79.96	2
70.47	8	86.01	1	95.44	3	80.66	2
71.27	0	86.97	1	5396.58	1	87.36	4
74.12	0	87.93	0	5402.76	1	89.53	1
75.58	2	93.02	0,Rh?	17.17	5	92.60	1
79.48	2	5197.71	1	18.88	0	5694.32	2, d
80.65	1	5200.15	1	21.70	1	5703.79	3
81.85	7	06.47	1	23.10	1	08.65	1
88.51	1	06.66	1	24.90	1	09.34	8
93.98	1	15.80	3	28.14	1	20.60	0
94.46	0	16.42	1	29.00	3	23.16	0
96.98	1	22.96	1	29.94	0	25.06	0
4999.72	12	30.38	3	30.44	0	25.29	4
5002.73	10	33.02	2	31.17	3	27.07	0
04.38	6	34.11	1	34.65	2	30.61	1
05.79	2	34.79	3,Pd?	38.81	1	31.77	3
09.16	7	37.52	1	41.15	0	32.90	0
14.22	2	38.92	10	42.83	2	34.05	1
15.00	10	40.10	1	46.75	5	36.24	6
16.34	1	43.70	3	49.50	30	44.37	0
18.97	0	45.51	2	54.50	10,+g,Ag	45.38	3
21.37	3	47.18	0	59.61	3	46.28	0
22.66	2	48.61	0	63.29	0	47.51	3
25.45	5	53.49	1	66.75	0	49.23	0
29.42	0	55.14	0	69.40	3	53.04	2
31.65	1	64.36	0	75.57	2	53.81	1
32.37	1	68.63	1	81.23	1,h	56.60	1
35.07	2	70.93	1	83.75	2	65.58	0
36.63	0	73.48	3	85.58	1	68.89	4
38.52	2	73.77	6	89.39	2	74.02	1
42.79	2	79.18	1,h	95.17	4	78.25	4
46.06	8	82.78	1	5497.11	2	82.36	2
46.27	3	83.68	3	5504.97	1	90.10	1
56.44	2	85.72	2	09.64	1	5795.69	1
58.43	1	86.90	1	13.53	2	5803.21	2
58.94	3	88.88	0	18.89	1	04.35	2
60.05	1	89.33	4	23.54	0,Os?	06.96	5
64.55	0	91.35	2	28.59	1	07.49	2
65.47	1	92.81	1	29.34	1	10.70	1
67.45	1	97.95	1	35.48	1	13.07	2
72.43	0	5299.47	1,h	40.62	3	15.12	2
82.41	2	5302.19	1	45.34	1,h	16.37	3
86.85	3	05.70	1	55.28	2	19.38	0
92.43	1	06.23	0	56.89	0	28.55	9
95.10	1	07.88	1	59.82	2	30.80	2
5099.18	2	11.79	2	61.43	0	32.48	2
5104.37	1	13.01	5	74.55	1	43.15	1
07.42	5	19.24	2	91.16	1	43.94	1
09.14	3	19.57	2,d	95.47	2	46.03	6
23.66	8	20.44	1	96.86	1	46.91	1
24.82	1	21.77	1	98.29	1	53.64	0
28.02	0	25.20	1	5599.94	1	62.37	1
28.96	3	29.21	5	5601.30	1	72.48	4
29.89	2	32.84	2	04.05	1	73.50	6
5131.53	5	5340.73	8	5607.25	0	5882.29	9

TABLE 5.—*Arc spectrum of iridium*—Continued

λ I. A.	Intensity and notes	λ I. A.	Intensity and notes	λ I. A.	Intensity and notes	λ I. A.	Intensity and notes
5883.04	0	6199.93	1, h, Rh?	6667.74	3	7101.06	3
85.35	2	6211.30	4	68.33	3	10.94	0
87.37	6	14.50	1	6686.08	7	18.19	0
94.06	15	16.53	0	6721.54	2	28.33	2
5899.58	3	17.41	2	33.12	2	35.99	0
5920.90	2	42.74	2	36.52	0	38.74	3
31.32	2	56.38	0	48.62	2	83.74	5
35.79	1	81.99	1	65.42	0	99.01	2
38.10	1	6288.28	7	76.11	1	7207.35	0, h, Fe?
45.78	2	6303.74	2	79.13	1	13.20	1
51.83	1	27.49	2	85.07	1	7214.97	1
54.82	1	34.44	6	6789.84	2	7331.94	0, h
60.68	3	6398.25	2	6814.18	0	63.60	0
73.57	2	6403.93	2	30.04	4	7376.85	0
83.97	1	18.36	3	83.04	0	7459.05	0
85.69	0	30.90	0, Fe?	86.23	2	7514.35	0
87.86	0	35.40	1	88.72	4	7596.16	1
89.37	1	48.69	2	6893.34	4	7623.22	0
5999.69	4	50.77	0	6905.31	0	43.22	1
6004.95	0	55.06	4	29.86	5	7660.71	1
12.72	1	72.04	1	48.94	0	7714.25	1
23.83	2	83.42	1	59.08	3	37.41	0
26.10	5	86.98	2	66.45	2	7760.40	0
36.65	3	6496.82	1	68.86	0	7834.32	5
48.04	0	6508.66	2	92.16	0	7891.14	0
60.56	3	18.88	0	6998.82	3	7925.90	1
65.62	1	40.29	2	7000.03	0	54.07	1
67.83	7	46.83	1	01.16	1	7989.23	0
69.90	0	52.26	2	07.63	1	8006.19	1
72.10	0	60.00	1	09.02	0	17.71	1
6083.12	2	66.09	1	22.96	1, h	8083.28	1
6106.00	1	84.93	0	37.85	4	8176.42	0
10.67	8	88.21	2	48.82	0	8182.42	0
14.53	2	6595.84	0	67.03	1	8228.32	0
23.01	2	6619.92	2	7071.78	0	8426.11	0
25.79	2	24.74	5				
27.82	1, h	27.58	0				
45.01	1	43.68	2				
51.56	0	59.22	2				
6187.37	1	6662.62	1				

TABLE 5a.—*Corrections to iridium tables*

Kayser	Exner and Haschek	Eder and Valenta	Suggested corrections	Kayser	Exner and Haschek	Eder and Valenta	Suggested corrections
5049.82(0)	----------	----------	5049.83 Fe (5)	----------	6216.34 (lu)	----------	6216.34 V (10)
----------	----------	5945.80 (3)	----------	----------	----------	6332.31 (3)	----------
----------	----------	5983.66 (3)	5983.56 Rh (10)	----------	----------	6496.97 (4)	6496.91 Ba (10)
----------	----------	6141.76 (4)	6141.74 Ba(10)				

6. PLATINUM (Pt=195.2; Z=78)

Nickel, palladium, and platinum occupy the same positions in their respective triads and their arc spectra are similar in that each contains the minimum number of lines compared with the other members of the triads. Kayser measured 67 lines in the interval 4511 to 5861A using Heräus platinum metal, which was regarded as comparatively pure although it contained considerable Ir. Eder and Valenta published 36 lines ranging in wave length from 5469 to 7114A; 22 of these are longer than 5861A. In photographing the visible

spectrum Exner and Haschek used electrodes of platinum metal from Heräus and they name Ag, Au, Cu, Ir, Pd, Rh, Ru, and Sn as impurities. Their table contains 79 lines between 4498 and 7258A. In addition to these observations, the arc spectrum of platinum has been measured relative to the international wave-length standards by Symons.[9] To the best of my knowledge this is the only arc spectrum of any element of the platinum group which has been heretofore described on the international scale. Symons gives 56 lines in the interval 4498 to 6710A.

Table 6 contains 239 lines with wave lengths ranging from 4498 to 8762A. All of the lines Symons found are represented here with practically the same wave length, except that his seven values above 6000A average 0.05A larger than mine. Lines given by other observers, but not represented in Table 6, are presented in Table 6*a* with suggested corrections.

TABLE 6.—*Arc spectrum of platinum*

λ I. A.	Intensity and notes	λ I. A.	Intensity and notes	λ I. A.	Intensity and notes	λ I. A.	Intensity and notes
4498. 75	20	4739. 76	3	5130. 91	2	5560. 02	2
4508. 59	2	47. 34	1	55. 38	2	5560. 12	1
11. 24	6	47. 88	3	64. 97	1	5619. 88	1
14. 14	1	50. 81	1	68. 05	1	63. 12	0
15. 66	2	68. 12	2	81. 84	0	84. 71	2
20. 91	15	72. 32	3	88. 88	0	5698. 98	3
23. 00	10	4779. 78	0	93. 91	3	5700. 46	2
34. 98	0	4804. 26	1	5199. 26	0	28. 14	1
36. 33	2	24. 24	1	5208. 59	2	40. 41	1
42. 46	0	31. 23	2	27. 66	20	50. 21	2
47. 88	8	31. 97	2	38. 47	1	62. 68	4
50. 08	0	53. 93	5	57. 48	3	5763. 59	6
51. 23	0	62. 40	2	60. 86	5	5822. 52	1
51. 94	3	79. 55	8	68. 24	1	38. 95	0
52. 42	12	81. 64	1	86. 12	3	40. 12	15
54. 59	6	93. 66	0	5288. 99	1	44. 82	10
55. 58	1	4898. 92	0	5301. 02	25	50. 64	0
60. 07	4	4908. 51	1	07. 65	1	60. 82	5
61. 15	1	34. 71	1	19. 34	3	72. 32	0
64. 56	1	40. 15	2	21. 60	0	5895. 08	0
65. 57	1	80. 40	3	23. 04	1	5902. 43	2, n, l
76. 28	1	86. 86	3	24. 59	2	64. 53	1, n?, l
77. 42	5	4997. 98	4	25. 90	1	79. 11	3
80. 52	3	5002. 65	4	28. 60	2	5988. 12	1
4580. 66	3	04. 44	1	40. 18	0	6005. 45	1, h
4612. 37	1	12. 03	1	42. 41	0	24. 24	4
17. 07	2	33. 64	5	68. 99	15	26. 03	7
20. 53	1	38. 54	2	87. 88	4	33. 67	1
29. 90	0	44. 04	10	5390. 80	10	40. 90	0
31. 12	2	53. 87	1	5400. 92	1	76. 87	4
39. 74	1	55. 36	1	52. 73	1	6098. 76	1
40. 82	5	59. 50	15	69. 49	2	6111. 62	1
50. 07	2	69. 50	1	75. 78	15	13. 30	0
57. 95	9	77. 80	2	78. 50	12	27. 08	1
83. 38	0	82. 35	2	85. 75	1	29. 17	1
4684. 10	5	86. 37	0	86. 97	0	41. 66	2
4701. 86	1	5095. 82	3	5488. 80	0	56. 38	0
18. 51	0	5108. 45	2	5514. 10	4	72. 56	4
36. 09	1	18. 44	2	21. 69	2	77. 53	0
4737. 57	4	5129. 54	0	5525. 85	4	6188. 77	0

[9] Symons, Zeitschr. Wiss. Phot. 12, p. 277; 1913.

TABLE 6.—*Arc spectrum of platinum*—Continued

λ I. A.	Intensity and notes	λ I. A.	Intensity and notes	λ I. A.	Intensity and notes	λ I. A.	Intensity and notes
6210.76	2, n, l	6597.93	2	7056.27	1	7786.78	3
16.00	5	6602.34	1	65.54	2	7790.22	1
37.66	3	48.31	6	78.08	3	7830.45	1
63.63	2	6655.54	1	7094.77	7	7877.42	0?
73.04	1	6710.39	10	7113.75	10	7911.26	1
82.25	2	6760.00	20	22.91	0	77.32	2
83.48	5	6820.23	2	25.05	1	7989.32	0?
6291.85	3	38.08	3	31.64	2	8007.48	0?
6318.36	7	42.60	8	7179.94	0	25.62	1, h
20.21	0	6896.74	2	7217.58	6		
						8093.88	1
21.66	1	6907.69	0	7396.95	0?	8204.45	3
26.58	10	08.80	2	7407.47	0?	24.79	6
32.88	0	10.02	0	7486.02	3	27.52	2
6398.88	3	34.11	0	7607.23	1		
6435.96	2	56.87	0	14.90	1	8259.03	1
						8301.87	1
72.25	0	57.50	3	18.20	2	8542.14	0, Ca?
6490.48	4	75.71	2	7626.27	1	8762.48	0
6523.44	15	6989.83	2	7738.60	1		
92.65	2	7011.95	0	49.74	2		
6595.61	1	7030.09	2	7780.53	2		

TABLE 6*a*.—*Corrections to platinum tables*

Kayser	Exner and Haschek	Eder and Valenta	Suggested corrections	Kayser	Exner and Haschek	Eder and Valenta	Suggested corrections
----------	4545.68 (1)	----------	4545.69 Ir (10)	----------	5208.93 (1u)	----------	5209.08 Ag (30)
4639.80 (4)	----------	----------	4640.82 Pt (5)	5274.84 (ou)	----------	----------	----------
4745.87 (1)	----------	----------	4747.88 Pt (3)	5295.75 (o)	----------	----------	5295.78 Ti (5) ?
----------	4810.49 (lu)	----------	4810.5 Rh (12) Zn (10)	5306.31 (o)	----------	----------	----------
				----------	6216.55 (1)	----------	----------
5037.68 (00)	----------	----------	----------	----------	----------	----------	----------
5044.46 (6)	----------	----------	----------	----------	----------	6288.54 (3)	----------
5049.83 (1)	----------	----------	5049.83 Fe (5)	----------	7257.76 (1u)	----------	----------
----------	5117.49 (1)	----------	----------				

IV. DISCUSSION

In the literature dealing with these elements there is almost no mention of band spectra. With the single exception of a band head at 4474A in the arc spectrum of palladium no band heads have heretofore been recognized in the arc spectra of any of the platinum metals. Although the spectrograms described above did not show bands with great intensity, they nevertheless permitted me to identify one or more band heads in the arc spectra of ruthenium, rhodium, osmium, and platinum. The bands thus far known for the platinum metals converge to heads toward short waves; that is, they are shaded to red; they are indicated by n, l in the tables.

Attention is called to the general aspects of the line spectra of these elements for the purpose of emphasizing some striking similarities as to relative complexity. The iron, cobalt, nickel group is included with the six platinum metals for a comparison of their spectra. The total number of lines observed by Exner and Haschek for each element in the three triads is as follows:

Fe (26) 2,392; Co (27) 1,830; Ni (28) 976
Ru (44) 1,948; Rh (45) 1,002; Pd (46) 268
Os (76) 1,340; Ir (77) 806; Pt (78) 461

It is of interest to extend this comparison to the new values in Tables 1 to 6. The number of lines with wave lengths exceeding 4500A which have now been published for these elements is as follows:

Fe (26) 1,100; Co (27) 895; Ni (28) 532
Ru (44) 1,260; Rh (45) 572; Pd (46) 172
Os (76) 942; Ir (77) 605; Pt (78) 239

The general tendency within any triad as well as between triads is for the number of lines to diminish as the atomic number increases.

Many attempts have been made to find regularities in the arc spectra of the platinum metals, and the literature contains a considerable number of examples of repeated wave-number differences which have been found. The high precision in relative wave lengths obtained by Kayser induced him to seek such relations in the spectra; his paper gives examples of constant wave-number differences in Pd, Pt, Ru. Further regularities of this type were pointed out for Rh by Snyder,[10] and Paulson [11] has published similar results for Pd, Pt, and Ru. Experience and simple probability theory have both shown that in complex spectra one may find a surprisingly large number of approximately the same wave-number differences of any given value and this in itself is not very strong evidence for the existence of regularities. Such evidence becomes more convincing when correlated with certain other spectroscopic data. For example, Kayser pointed out that 24 of the strongest Pd lines (19 out of the total of 34 observed as reversed in the arc) involve the separations 1,191.2 and 3,967.9, but these differences do not appear among any of the diffuse lines. There can be no doubt that these separations are significant, although the complete interpretation of them is not yet at hand. The recent success in analyzing other complex spectra has been due in large part to the existence, in addition, to wave numbers and estimated intensities, of various other spectroscopic facts, such as temperature classification, Zeeman effect, pressure shift, etc., which assist in the detection of multiplet structures and spectral terms. A relatively large number of accurately observed data of all these different types has made it possible to establish relations between nearly 1,000 of the lines of the arc spectrum of iron and this is the first element in Column VIII of the periodic system whose spectrum has thus far been resolved into its main features.

Unfortunately, similar data for the elements of the platinum group are entirely lacking except for very meager results of more or less qualitative nature on Zeeman effects and pressure displacements. The arc spectrum of ruthenium and of osmium should resemble in structure the arc spectrum of iron. Rhodium and iridium are expected to resemble cobalt and the structure of the arc spectrum of

[10] Snyder, Astroph. Jour., 14, p. 179; 1901.

[11] Paulson, Phil. Mag. (6), 29, p. 154; 1915; Ann. d. Physik., 46, p. 698; 1915; Physik. Zeitschr., 16, p. 81; 1915.

palladium and of platinum should be similar to that of nickel. Considerable preliminary work has been done to prove this in detail and the results of these investigations will appear in future papers. When the opportunity comes, additional observations will be made on the ultra-violet spectra of these pure metals so that complete descriptions will be available. Although the fainter lines have relatively little importance in spectrochemical analysis they are just as uniquely characteristic of the chemical atom as the stronger lines. From the standpoint of analysis and interpretation of complex spectra the faint lines are not to be neglected, since they represent in many cases the less probable transitions in complete multiplet structures, and usually the intersystem combinations of spectral terms are represented by relatively weak lines.

Remembering the large amount of labor involved in securing the wave-length data presented in this paper, I wish to express grateful acknowledgments to Mrs. F. J. Stimson for making some of the exposures and assisting with the computing.

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